(NASA-CR-165462-A) CELL MODULE AND FUEL CONDITIONER DEVELOPMENT Quarterly Report, Jul. - Sep. 1981 (Westinghouse Electric Corp.) 33 p HC A03/MF A01 CSCL 10A

N83-12524 [redacted]

Unclas
G3/44 01247

DOE/NASA/0161-9A
NASA CR-165462-A

CELL MODULE AND FUEL CONDITIONER DEVELOPMENT

8TH QUARTERLY REPORT: JULY - SEPTEMBER, 1981

J.M. Feret
Westinghouse Electric Corporation
Advanced Energy Systems Division
Pittsburgh, PA. 15236-0864

October, 1981

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN 3-161

for
U.S. DEPARTMENT OF ENERGY
Energy Technology
Division of Fossil Fuel Utilization
Under Interagency Agreement DE-AI-01-80ET17088

DOE/NASA/0161-9A
NASA CR-165462-A

CELL MODULE AND FUEL CONDITIONER DEVELOPMENT

8TH QUARTERLY REPORT: JULY - SEPTEMBER, 1981

J.M Feret
Westinghouse Electric Corporation
Advanced Energy Systems Division
Pittsburgh, PA. 15236-0864

October, 1981

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN 3-161

for

U.S. DEPARTMENT OF ENERGY
Energy Technology
Division of Fossil Fuel Utilization

TABLE OF CONTENTS

I. INTRODUCTION

This report is for the second Phase of a six Phase program to develop commercially viable on-site integrated energy systems (OS/IES) using phosphoric acid fuel cell (PAFC) modules to convert fuel to electricity. Phase II is a planned twenty-seven (27) month effort to develop appropriate fuel cell module and fuel conditioner conceptual designs. The fuel cell module development effort involved comprises four coordinated tasks:

- Task 1: Design of Large Cell Stacks
- Task 2: Stack Fabrication
- Task 3: Stack Testing
- Task 5: Management Reporting and Documentation

The work accomplished during this reporting period, 7/15/81 thru 9/30/81 inclusive, is described at the subtask level in the following section.

II. TECHNICAL PROGRESS SUMMARY

TASK 1: DESIGN OF LARGE CELL STACKS

1.2 Stack Design

10 kW Stack Design

The approach taken in design of the 10 kW stack is to make it as prototypic as possible of the full size module design, especially in mechanical detail. Thus, the development process during scale up will have fewer detail changes resulting in better verification and less overall schedule and cost risk.

The 10 kW stack design is based on operating parameters of up to 150 psia pressure, 204°C cell temperature, 400 mA/cm^2 current density, 0.92 open circuit voltage and 0.68 volts/cell. For safety reasons and to facilitate the design of the fuel and oxidant manifolds, a requirement to maintain the oxidant/coolant stream pressures above those of the fuel stream by 5" H_2O as a minimum was defined. The design operating point is covered by these values and will result from system trade studies still in progress.

The Westinghouse Research and Development Center Mark II plate drawings defining the zee and treed configurations were assumed, thereby establishing 16.25 inch x 11.5 inch as final plate dimensions. Considering the above, the design layout incorporates 44 cells in 8 groups of 5 cells each separated by cooling plates and with 2 cells at each end of the stack. The resulting stack active length is approximately 11.5 inches. The stack is clamped between two compression plates, with the clamped length fixed. As a result, the relative motion between the stack components and the manifolds seals is reduced to essentially zero.

The 10 kW stack design incorporates a single stack supported inside a pressure vessel in a manner which duplicates the method to be used in a full size four-stack module. A plenum box structure simulates the cooling air exhaust passage created by the four stack array. All of the support features, sealing provisions,

manifold and piping arrangements envisaged for the four-stack module are realistically duplicated in this layout. The piping and manifold flow area sizing is consistent with its eventual use in a full stack and module. Accommodation of full stack components requires only the lengthening of the mid-section of the assembly components such as manifolds, pipes, and vessel. In this way, the development experience to be accumulated in the testing of single 10 kW stacks will be applicable to the full stack modules. Electrical connections to the copper collector plates are provided along the plate edge, clear of the stack, to provide a positive attachment, independent of the stack clamping forces. The thickness of the insulator plates is approximately 2 inches in order to provide resistance to arcing under 1500V open circuit voltage conditions anticipated in the full module design.

Consideration was given in the design work as to the relative merits of in-series and in-parallel module-to-power conditioner connections. Normal operating point module voltage is expected to be in the region of 1100V. This voltage, however, can increase to approximately 1500V under open-circuit conditions. Connecting 20 modules in-parallel limits the voltage, which must be accommodated by the internal module insulation, to 1500 volts. This results in a large current and heavy connector bus at the power conditioner. A series connection limits the current to approximately 375 amps but results in extremely large voltages which complicate the provision of the necessary electrical insulation. It is presently judged that two modules in series with ten parallel circuits is the best arrangement. Moreover, by operating half the complement of modules at above-ground and the other half at below-ground potential, a sufficiently high normal operating point (2200V and 3750A) can be provided to the power conditioner to facilitate the design of that system, without increasing the individual module operating voltage of 1100V.

During this quarter, the preliminary concept layout drawing of the 10 kW stack was completed and copies distributed internally to cognizant engineering discipline personnel for their review and comment. The design was also reviewed with NASA personnel during the September 23, 1981 Project Status Review Meeting. In accordance with the internal comments received, updating of the design layout has been initiated. The most significant changes include the incorporation

of flow distribution orifices in the stack process gas manifolds, an increase in the molded plate size from 12.125 inch x 17.125 inch to 12.375 inch x 17.375 inch to provide increased shim widths, and reinforcement modifications to the pressure vessel penetrations as identified by structural analysis to comply with ASME pressure vessel code requirements. Comments received from potential plastic manifold vendors resulted in the redesign of the manifolds to eliminate stiffening ribs and minimize variations in thickness. A leaf spring arrangement has been incorporated to transfer the clamping force to the manifold centerline to ensure positive sealing at this location in the absence of the stiffening ribs.

Detail drawings of the molded zee-channel and tree cooling passage plate configurations were prepared. These drawings will be submitted early next quarter to Westinghouse Research and Development Center and ERC personnel and mold die vendors for review. Plate drawings incorporating the results of this review will be prepared for final release to obtain dies (under the Westinghouse supported program).

Some consideration was given to the orificing requirements of the stack process gas manifolds to ensure that the 10 kW stack design is as prototypic as possible and fully applicable to the larger stacks and complete module. It is now intended that the stack process air will be piped from the exhaust plenum between the four stacks rather than from the cooling air inlet plenum. This change was made to increase the process air inlet temperature.

A report is in progress which summarizes the results of an evaluation performed for interfacing the fuel cell modules with a current sourced inverter. The DC interconnections from the modules to the inverter will be consolidated into a single two terminal input to the inverter. The consolidation circuitry requirements have been defined. A reasonable compromise position was resolved between the need for obtaining high fuel cell output voltage and minimizing insulation design problems. By connecting the plus side of one half the modules and the minus side of the other half to a ground bus, a total voltage of 2200 volts will be obtained. Since one side of each fuel cell module is grounded, one switching device will be needed to connect each module to a DC bus. Three methods are being evaluated:

(1) high speed DC (mechanical) circuit breakers, (2) solid state electronic switching devices, and (3) diodes with manual mechanical switches.

Establish Technical Constraints

An assessment of available and developing phosphoric acid fuel cell (PAFC) technology was conducted and a report completed summarizing the currently perceived technical constraints and conclusions. Pertinent PAFC technology parameters are listed in Table 1.2-1. The first column summarizes the current best estimate of operating parameters and the second column indicates the anticipated improvements associated with a nominal two year development program completion.

The principal conclusions resulting from this effort are summarized as follows:

1. Although insufficient trend data, parametric sensitivities and interaction effects data exist to firmly establish accurate design and operating technical constraints, there are sufficient performance data to assure a high probability of reaching/exceeding anticipated performance of 300 to 400 mA/cm^2 current density at 0.71 to 0.72 volts per cell at a operating temperature of 204^oC (400^oF), (second column of Table 1.2-1).

2. A significant component performance characterization test effort is needed to establish characteristic data, life trend data, and parameter trade-off sensitivities to assure design with optimal performance and predictability.

A summary of the key design constraints as currently perceived is shown in Table 1.2-2. This table will be updated as trend data and parameter sensitivities become established with time.

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 1.2-1. PAFC TECHNOLOGY OPERATING PARAMETERS

	Best Estimate with Current Technology as Demonstrated with Various Singular Experiments (Non-Production/Oper.)	Potential Technology Capability for Repeatable Production (with 2 year Development Program)	Comments
F.C. Current Density (mA/cm^2)	200-400 (1)	300-400 (1)	Nominal design expected ~325 at 50 psia pressure
F.C. Voltage (V/cell)	0.65 - 0.70	0.71 - 0.72	≥50 psia pressure condition
Limiting Voltage (V/cell)	<0.80	0.8	Corrosion impact is not understood. Development needed regarding control limit
Minimum Current Density (mA/cm^2)	50-75	(tbd)	
F.C. Oper. Temp. (°C)/(°F)	177-190 (1) (350-375)	204 (2) (400)	Max local temp. < 220°C Nominal design temp. ~200°C may be found acceptable with low Δt. Cell/stack max. to avg.
Max. Oper. Temp (°C)/(°F)	~200 (~398)	>200-220 (3) (398-426)	
Pressure Level (psia)	50-65	>50-150	System dependent
Oxidant Air Stoich (Avail O_2/O_2 reqd)	2-4	<2	Impact system performance through compressor power required
Fuel Utilization Max (%)	80 — 85	85-90 (tbd)	
Transient Rates:			
Power increase (startup)	(tbd)	(tbd)	System application and operating mode dependent. Both cold start and hot start data needed
Shutdown (normal)	(tbd)	(tbd)	
Shutdown (emerg.)	(tbd)	instant (tbd)	
Load Increase (shunt)	(tbd)	(tbd)	
Cell Internal Resistance (mV/100 mA/cm^2)	10 — 20	<10	Impacts clamping load and interface surface area constraints
Cell Open Circuit Voltage (Vmax)	0.92 - 1.1	(tbd)	Design for potential >1.1 is prudent (theoretical is 1.144)
Max. Electrode bubble pressure (psi):			
Cold Conditions	20-60	>50	
Oper. Conditions	(tbd)	(tbd)	
Stack Compressive Max. Load (psi)	20-60 (4)	(tbd)	Impact on contact resistance and on leakage needs to be determined.
" " Min. " "	~1 (tbd) (5)	(tbd)	
Coolant Inlet Tem. (°C):/(°F)			
Steady State Min. Oper.	120 (250)	120 (250) (tbd)	Need sys. eval. for T.O. on Aux. Power, perf. & cost.
Steady State Max. Oper.	190 (375)	200 (375) (tbd)	
Coolant Press. Drop (in. H_2O)	1-10	(tbd)	Recirculating power constraint (Higher pressures reduce ΔP and may incur a distribution problem)
Process Oxidant Press Drop (in. H_2O)	1-10	(tbd)	
Process Fuel Press Drop (in. H_2O)	0.1-0.5	(tbd)	
Reactant Press. Diff (in. H_2O)	0.5-10	(tbd)	
Max. Stack Voltage (V_{dc})	< 400	-	Result from est. stack height-- not constraining to design-- Interfacing with power conversion >2000 Vdc for efficient design
Nominal Stack Voltage (V_{dc})	< 300	-	
Minimum Modular System Output Voltage (V_{dc})	>2000	>2000	

1) Trade-off needed to establish best value based on efficiency loss vs cost $/kW.

2) Demonstrated for moderate lifetimes by UTC (~3000 hrs)

3) Limited by corrosion. Electrolyte evaporation and catalyst degradation yet to be assessed.

4) ERC experience (beginning of life conditions) and potential for loss of containment pressure

5) Relaxed condition.

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 1.2-2. KEY PAFC SYSTEM AND DESIGN CONSTRAINTS(1)

CONSTRAINT IDENTITY	TIME	LEVEL	ORIGIN/COMMENTS
Maximum Voltage (Cell)	Continuous	< 800 mV	Corrosion Constraint from life perf. req't.
Maximum Voltage (Cell)	(tbd) Hrs	O.C. (~1000 mV)	Functional Constraint - max. design voltage req't.
Minimum Voltage (Cell)	--	None	" " - min. " " "
Current Density (Min)	(tbd) Hrs	0-75 mA/cm^2	Corrosion Constraint - Voltage dependent - requires further devel. data to set time limit at temp
Current Density (Min)	Continuous	> 75-100(2) mA/cm^2 (tbd)	Corrosion Constraint - function of temp. & press. & not yet characterized.
Current Density (Max)	Continuous	< 400 mA/cm^2 (tbd)	Performance Constraint- low efficiency - requires efficiency versus cost trade-off (TO).
Temperature (Nom. Max)	(tbd) Hrs	220°C (426°F)	Performance Constraint from life req't. & impact of electrolyte loss.
Temperature (Max)	Continuous	(tbd) 190-200°C (375-398°F)	Performance Constraint from temp. control - var. and max ΔT in cell.
Temperature (Min)	Continuous	(tbd)	" " " " " " & CO poisoning
Pressure (Max)	Continuous	< 150 psia (tbd)	" " " T.O. studies - cost vs press. level needed
Pressure Diff. Containments (Max)	Instant	150 psid (tbd)	Functional Constraint - design condition imposed on cell assy. and sealing.
Temperature Coolant (Max)	Continuous	(tbd) 110-150°C (230-302°F)	Performance Constraint- temp. control of cell and coolant characterization.
Temperature Coolant (Max)	(tbd) Hrs	(tbd) 200°C (398°F)	Performance Constraint- life req't. impact from excess cell temp. cond.
Cell Coolant Diff. Press. (Max)	Instant	(tbd)	Functional Constraint - design limit for reactant separation req't and cell assy. and sealing.
Reactant Diff. Press. (Max)	Continuous	(tbd)	Functional Constraint - "
Cell Stack Temp Diff (Max to Min)	(tbd) Hrs	(tbd) 20-50°C (36-90°F)	Performance Constraint- life req't. impact.
Cell Stack Temp Diff (Max to Min)	Continuous	(tbd) ~20°C	" " " " "
Transient Rates - Power	Startup Shutdown	(tbd) (tbd)	" " " " "

TABLE 1.2.2. KEY PAFC SYSTEM AND DESIGN CONSTRAINTS
(continued)

CONSTRAINT IDENTITY	TIME	LEVEL	ORIGIN/COMMENTS
Stack Mechanics:			
Contact Resistances	Continuous	(tbd) <20mΩ-cm^2	Performance Constraint for practical losses (<2% output)
Clamping Load (Initial)	Continuous	(tbd) 20-60 psi	Performance Constraint - leakage and electrical losses
Clamping Load (Min)	Continuous	(tbd) >1 psi	
Creep Rates/Strengths	--	(tbd)	" " - hi contact resistance
Relaxation Rates	--	(tbd)	" " - life req'ts. impact
Max Stack Height (Module)	--	3.3 m	" " - truckability
Max Width (Module)	--		" " "
Max Weight (Module)	--		" " "
Max Output Voltage (Stack)	Instant	(tbd) < 400 Vdc	Functional Constraint - design limit is fixed as function of no. cells in stack at O.C. voltage
Max. Output Voltage (Stack)	Continuous	(tbd) < 300 Vdc	- nominal design condition
Min Output Voltage (Module)	Continuous	> 2000 Vdc	Functional Constraint - nominal design condition Performance Constraint - Conversion efficiency.

(1) Condensed list of key constraints remaining after having assumed fixed process controls and fixed perf. parameters for baselined reference design. These parameters are needed for further design and operating requirements definition as derived from functional and/or performance requirements. (The predominating requirement is noted as origin of constraint).

(2) Corrosion impact - not yet understood and varies with temperature.

1.3 Full Scale Module Design

System Analysis/Trade Studies

Preliminary studies on the effect of pressure and temperature on fuel cell plant performance and economics were performed and are near completion. Heat rates, fuel cell system size and fuel cell module replacement rates were estimated for 30 cases. Table 1.3-1 summarizes the plant performance for these 30 cases. The effects of pressure and average cell temperatures are shown in Figure 1.3-1 on heat rate. The results show that the effect of temperature is significant, while the effect of pressure is relatively small. The effect of current density on heat rate is shown in Figure 1.3-2 at a average cell temperature of 190°C.

The baseline direct capital costs were developed for the prototype, first production unit and projected commercial plant. Algoritnms to compute the impact on direct plant capital cost, fuel cell cost, and fixed O & M costs were developed for the performance parameters. These algorithms were used to compute the impact on total plant costs. Figure 1.3-3 is a typical illustration of the impact of pressure on direct capital cost, fixed O & M and and reload costs. This is representative of the parametric data base generated which is being used as input to a computer code to generate the cost of electricity.

An evaluation of various power control methods was completed. Three specific methods were considered: variable pressure, constant pressure, and average cell temperature. An assessment of the availability and performance (flow control and efficiency) for industrial compressors including centrifugal, reciprocating, and rotary screw types was made. Based upon the results of this study, constant pressure operation featuring a rotary screw compressor for the air supply was selected as the preferred power control method. The rotary screw compressor has the following advantages in this application: high efficiency over a wide operating range using speed control, efficiency and capacity do not degrade with life, low maintenance, low noise level, and low cost.

TABLE 1.3-1. PERFORMANCE SUMMARY OF 7.5 MW_e DC PAFC SYSTEMS

P (atm)	T (°C)	CURRENT DENSITY (mA/cm^2)	CELL VOLTAGE (volt)	POWER DENSITY ($watt/cm^2$)	TOTAL # OF CELLS	NET ac POWER OUTPUT (kW_e)	PLANT EFFICIENCY (%)	HEAT RATE (Btu/kWh)
3.4	190	200	.762	.152	42380	6948	43.0	7936
		323	.702	.227	28480	6940	39.6	8625
		400	.662	.265	24390	6924	37.2	9167
1.0	177	200	.675	.135	47820	6934	38.0	8973
		323	.615	.199	32500	6907	34.5	9887
		400	.575	.230	28070	6885	32.2	10603
5.0	180	200	.765	.153	4222[illegible]	6729	41.8	8164
		323	.705	.228	28370	6710	38.4	8885
		400	.665	.266	24290	6694	36.1	9442
4.8	200	200	.796	.159	40590	6888	44.5	7666
		323	.735	.238	27190	6898	41.2	8282
		400	.696	.278	23210	6920	39.1	8731
7.0	170	200	.755	.151	42790	6552	40.2	8499
		323	.695	.224	28790	6509	36.7	9293
		400	.655	.262	24670	6474	34.4	9915
7.0	190	200	.800	.160	40370	6718	43.6	7820
		323	.740	.239	27030	6706	40.3	8469
		400	.700	.280	23070	6701	38.1	8960
2.5	180	200	.730	.146	44240	6951	41.2	8282
		323	.670	.216	29850	6939	37.8	9039
		400	.630	.252	2563[illegible]	6909	35.3	9655
1.8	170	200	.696	.139	46400	6940	39.2	8700
		323	.636	.205	31440	6914	35.7	9557
		400	.596	.238	27090	6896	33.4	10225
10.0	180	200	.794	.159	40690	6532	42.1	8105
		323	.734	.237	27250	6496	38.7	8816
		400	.694	.278	23270	6474	36.5	9356
10.0	190	200	.817	.163	3954[illegible]	6615	43.9	7778
		323	.757	.244	264[illegible]	6596	40.5	8420
		400	.717	.287	225[illegible]	6587	38.3	8901

ORIGINAL PAGE IS
OF POOR QUALITY

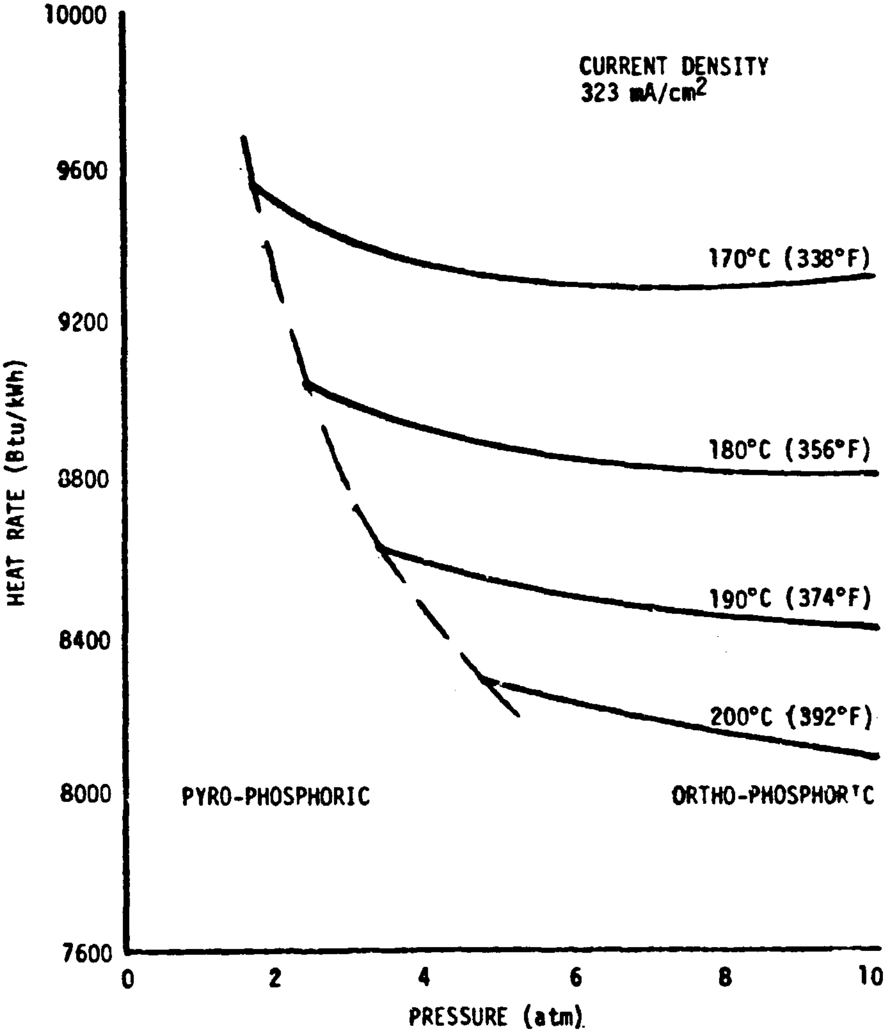

Figure 1.3-1. PAFC Heat Rate versus Pressure at Various Average Cell Temperatures

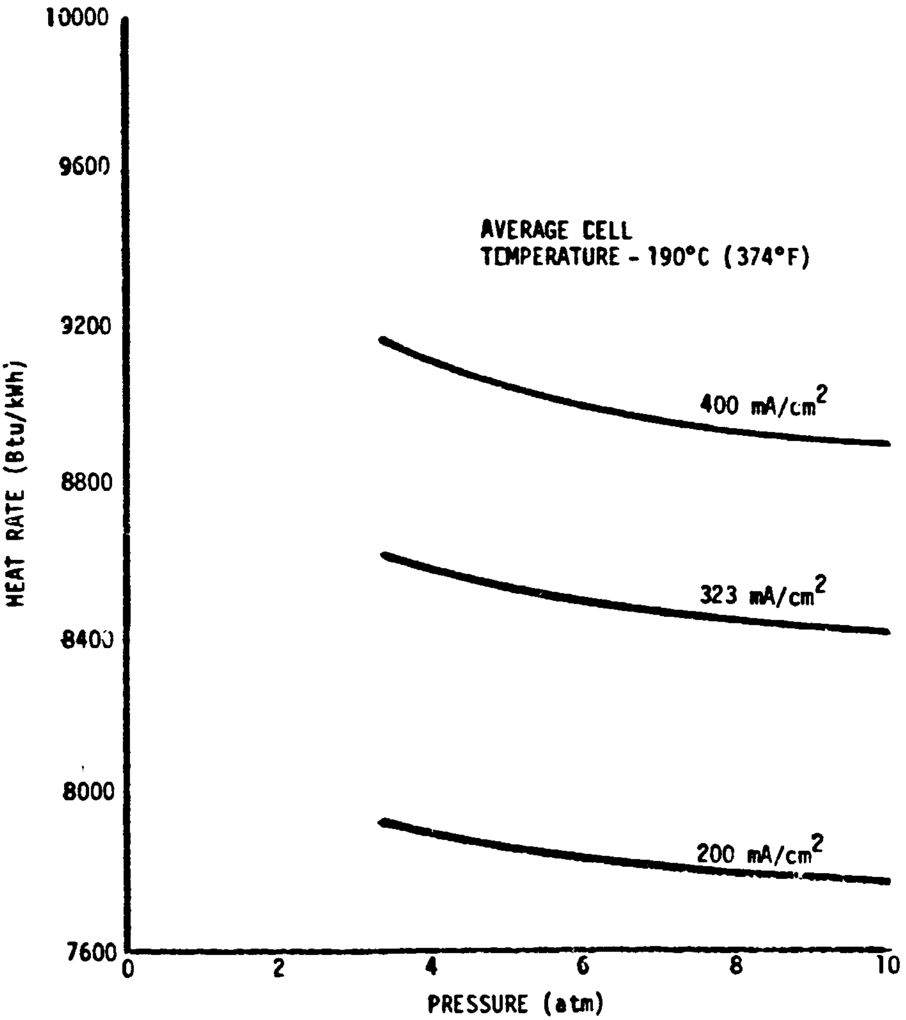

Figure 1.3.2 PAFC Heat Rate versus Pressure at Various Current Densities

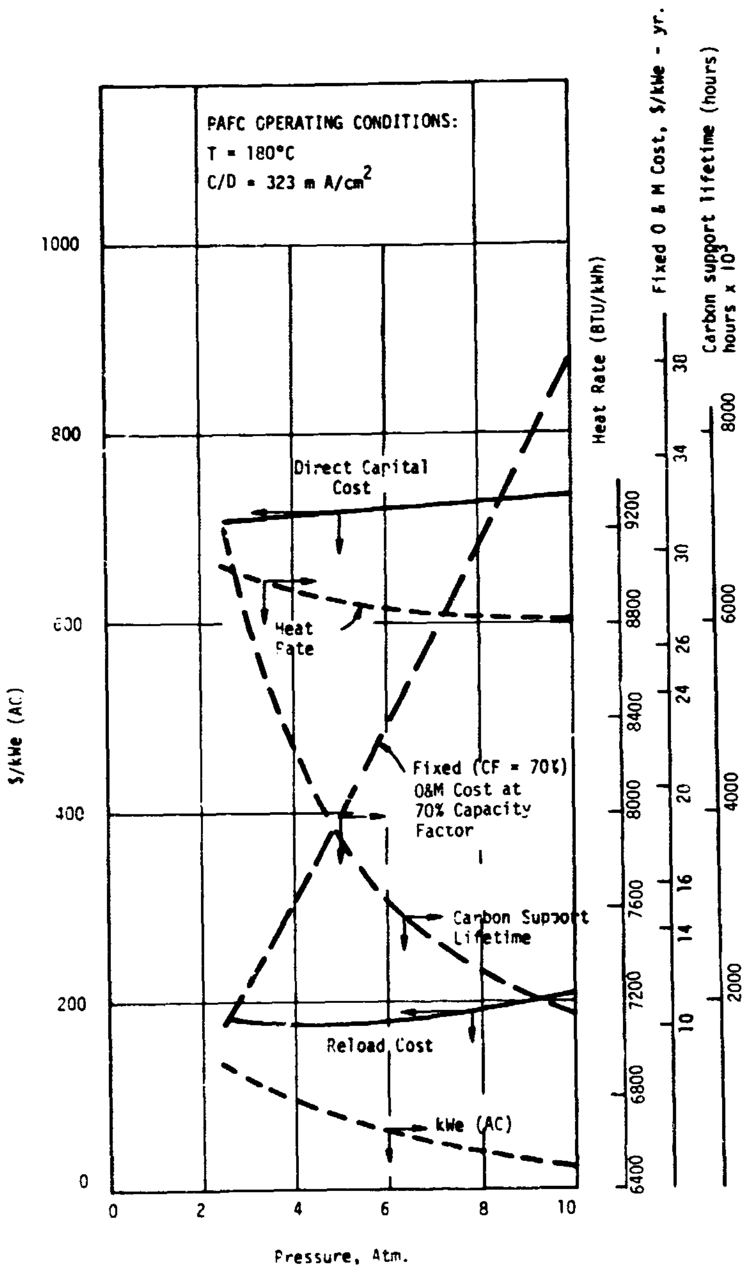

Figure 1.3-3. Projected Commercial Units

Variable pressure operation over the operating range ruled out effective use of a centrifugal compressor since at reduced flow and outlet pressure, a reduced speed would be required. Vendors contacted indicated that the compressor's design point speed was over the first critical speed and therefore variable speed operation is not possible. The minimum acceptable speeds for reciprocating compressors are about 75% of design speed. This results in limited capacity control.

A study to evaluate the effect of power level on plant capital costs and cost of electricity was essentially completed. Plant performance was estimated for power levels ranging from 1.5 to 15 MW. The effect of size on heat rate (efficiency) is small with the heat rate ranging from 8760 Btu/kwh for the 1.5 MW plant down to 8580 Btu/kwh for the 15 MW plant. The baseline plant capital cost used in this study was $2726/kWe. Algorithms for estimating the effect of power level on direct capital costs were developed for the fuel cell system and the fuel processor system. Algorithms will be developed next quarter for the power conditioning system and rotating equipment. Traditional scaling factors will be used for the balance of plant equipment.

Development Requirements

A number of parameters having technical constraints were defined on Table 1.2-2 in Subtask 1.2 as to-be-determined (tbd). Most of these are related to the large uncertainties associated with the impact of life trends (corrosion, degradation from impurities, etc.) and stack mechanics. Effort was initiated to develop a suitable test program and specific test plans and designs that would permit the maximum results using statistically designed experiments. Early materials and process verification testing has been defined to accommodate this objective. These tests will comprise the first designed experiment sets for developing component characteristics needed for trend data for design. Test planning and design efforts associated with the 10 kW stack and unit stack definition also relate to these development requirements.

TASK 2: STACK FABRICATION

2.2 Simulated Stacks

A detailed review of the available ERC fuel cell stack assembly procedures was completed. Updating of these procedures based upon observing the assembly of

stack 564 at ERC and our own experience was initiated and is continuing. These procedures will be utilized when completed to assemble a 23 cell stack that is essentially identical to stack 561 and thereby demonstrate the state-of-the-art manufacturing transfer from ERC to Westinghouse. Likewise, review of the ERC process procedures for manufacture of all cell repeatable components was completed and procedures prepared. Traning of manufacturing personnel in utilizing these initial procedures was initiated and is continuing.

All of the required assembly materials such as teflon shim stock, gaskets, viton cement, phosphoric acid, etc. needed for the above mentioned stack have been placed on order. To date, most of these items have been received and receiving inspection completed. Also, fabrication of all non-repeatable components required for this stack such as compression plates, haysite insulators, tie bars and rods, terminals, etc. were completed.

All manufacturing activities associated with the fabrication of bipolar plates (straight-thru channels) for this stack were completed. These completed plates, which include a number of spares, have all passed the required leak check and are currently being examined in detail. Initial problems incurred with earlier produced plates in terms of non-uniform plate thicknessness on the order of 0.010 inches were resolved via revising the powder distribution and pressing cycle.

TASK 3: STACK TESTING

3.8 Materials Testing

Raw Materials Characterization

Various raw materials' suppliers were contacted to obtain their input in order to prepare suitable specifications for procurement and control of all fuel cell raw materials. The status of this effort is summarized in Table 3.8-1. To date, six vendors have responded to our inquiries. These replies either contained very minimal information or were very detailed.

The chemical analysis listed in Table 3.8-2 is planned for the raw material characterization. Representative samples were taken for the raw materials identified and analysis will be initiated as soon as the final quotation in response to our requisition is received.

TABLE 3.8-1. FUEL CELL RAW MATERIAL VENDOR INQUIRY STATUS SUMMARY

SUPPLIER	RAW MATERIAL	VENDOR SUPPLIED		COMMENT
		PROCESS SPECIFICATION	PRODUCT SPEC. BULLETIN	
Carborundum	1000 grit green SiC	Yes		
DuPont	Teflon 6C Teflon 30 Teflon 120	No No No	Yes Yes Yes	
Reichhold Chemical, Inc.	29-703 Varcum	No	Yes	
Asbury Graphite Mills, Inc.	A-99 graphite powder	No	No	Supplied typical analysis
Stackpole	PC-206 graphite paper	No	No	Indicated few internal controls enforced
Cabot Corporation	Vulcan XC-72	No	Yes	
Guard-All Chemical Co., Inc.	Shell Sol 340			Response not yet received
Johnson-Matthey, Inc.	10 wt percent Pt Catalyst on Vulcan XC-72 carbon black			Response not yet received

TABLE 3.8-2. CHEMICAL ANALYSIS FOR STARTING MATERIALS

MATERIAL	ELEMENTS TO BE ANALYZED
A-99 graphite, XC-72 carbon black, PC-206 graphite paper, 1,000 grit green SiC powder, 29-703 Varcum, Teflon 6C, Teflon 30, Teflon 120	Pb, Fe, Al, V, Mn, Cu, Si, Na, Ti, Ni, Mg, Cr, Cu
A-99 graphite, XC-72 carbon black, PC-206 graphite paper	Sulfur

Fuel Cell Component Characterization

The first heat treatment run of bipolar plates was completed thus making available a preliminary group of plates for characterization. This group of plates included both conventionally formulated graphite/resin plates and plates produced utilizing an internal mold release agent. Visual examination indicated the absence of blistering and cracking. Shrinkage of about 4 percent in length and width, and about 6 percent in depth occurred during the heat treat cycle.

Samples from fabricated electrodes were submitted to Particle Data Corporation, Elmhurst, Illinois, to obtain mean pore size data by mercury intrusion. Samples submitted included as-received backing paper, the catalyzed layer, and the backing paper from which the catalyzed layer was removed.

Subscale Fuel Cell Component Testing

Subscale Test Cell No. 14 (2 inch x 2 inch size) was assembled using AESD produced electrodes and carbonized end plates provided by ERC. The following data is applicable to the electrochemical components used in this test:

Anode:	0.34 mg Pt/cm^2 (A-015-2/40)	18 mils thick	
Cathode:	0.52 mg Pt/cm^2 (C-014-2/33)	26 mils thick (includes SiC layer)	

Gaskets: Anode - 10 mils thick
Matrix - 10 mils thick
Cathode - 10 mils thick

Test Cell No. 14 was assembled and the test initiated on July 22, 1981. The open circuit voltage measured prior to test initiation was 0.828V. Test conditions were 177^{o}C, air flow rate of 670 mℓ/min (approximately 7 stoich), and a hydrogen flow rate of 53 mℓ/min (approximately 70% hydrogen utilization). The terminal cell voltage history at these conditions is plotted in Figure 3.8-1. As shown, the cell voltage increased with time. After about 200 hours, the position of the exhaust gas exit tubes was readjusted to reduce the back pressure on the cell. Initially, the cell back pressure was approximately 5 inches of water which was adjusted to less than 1 inch. This is assumed to account for the decrease in cell potential. The cell voltage after this adjustment showed a

ORIGINAL PAGE IS
OF POOR QUALITY

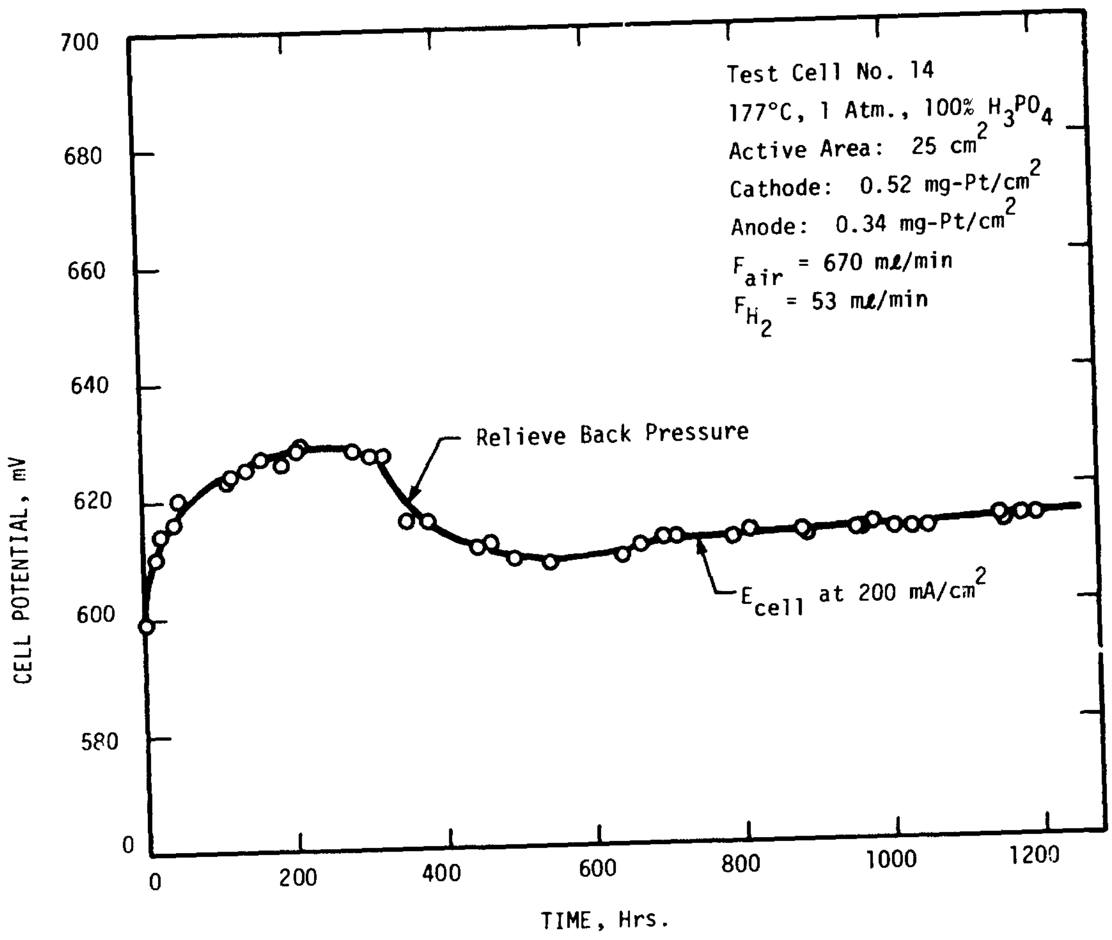

Figure 3.8-1. History for Test Cell No. 14

slight but continued increase up to termination of the test. Polarization data for Test No. 14 after 1,000 hours of testing is given in Table 3.8-3.

As shown in Figure 3.8-2, the performance of Test Cell No. 14 is comparable with Test Cell No. 10.

Test Cell No. 15 was assembled and testing initiated on September 15, 1981. The component data for Test Cell No. 15 is as follows:

Anode:	0.34 mg Pt/cm^2 (A-015-4/35)	17 mils thick
Cathode:	0.52 mg Pt/cm^2 (AC-014-7/37)	26 mils thick (Includes SiC Layer)
Matrix:	ERC-supplied component	7 mils thick
End Plates:	Carbonized, ERC supplied	
Gaskets:	Anode - 10 mils Cathode - 15 mils Matrix - 10 mils	

The test conditions were the same as for Test Cell No. 14. The initial cell voltage was 0.528V and increased continually to 0.603-0.605V after 406 hours of testing at which time performance stabilized. The test was terminated on October 5, 1981 after accumulating 563 hours.

The subscale unpressurized test facility (consists of 25 individual test stands) fabrication and installation is underway. This facility is planned for full operation by mid-November.

TASK 5: MANAGEMENT REPORTING AND DOCUMENTATION

5.1 Supervision and Coordination

Effective July 1, 1981, in accordance with Contract Modification 6, prime responsibility for this contract was transferred within Westinghouse from the Research and Development (R&D) Center to the Advanced Energy Systems Division (AESD). Effort to be performed by the Westinghouse R&D Center and their major subcontractor Energy Research Corporation remains unchanged except that it was continued under a partial order transfer from Westinghouse AESD.

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 3.8-3. POLARIZATION DATA FOR SUBSCALE TEST NO. 14
AFTER 1,000 HRS OF OPERATION AT 177°C

(Cell Resistance 6.3 mΩ)

CURRENT DENSITY (mA/cm^2)	CELL TERMINAL VOLTAGE
Open Circuit	0.878
80	0.710
120	0.680
160	0.656
200	0.634
240	0.613
280	0.594
320	0.575
360	0.550
400	0.535

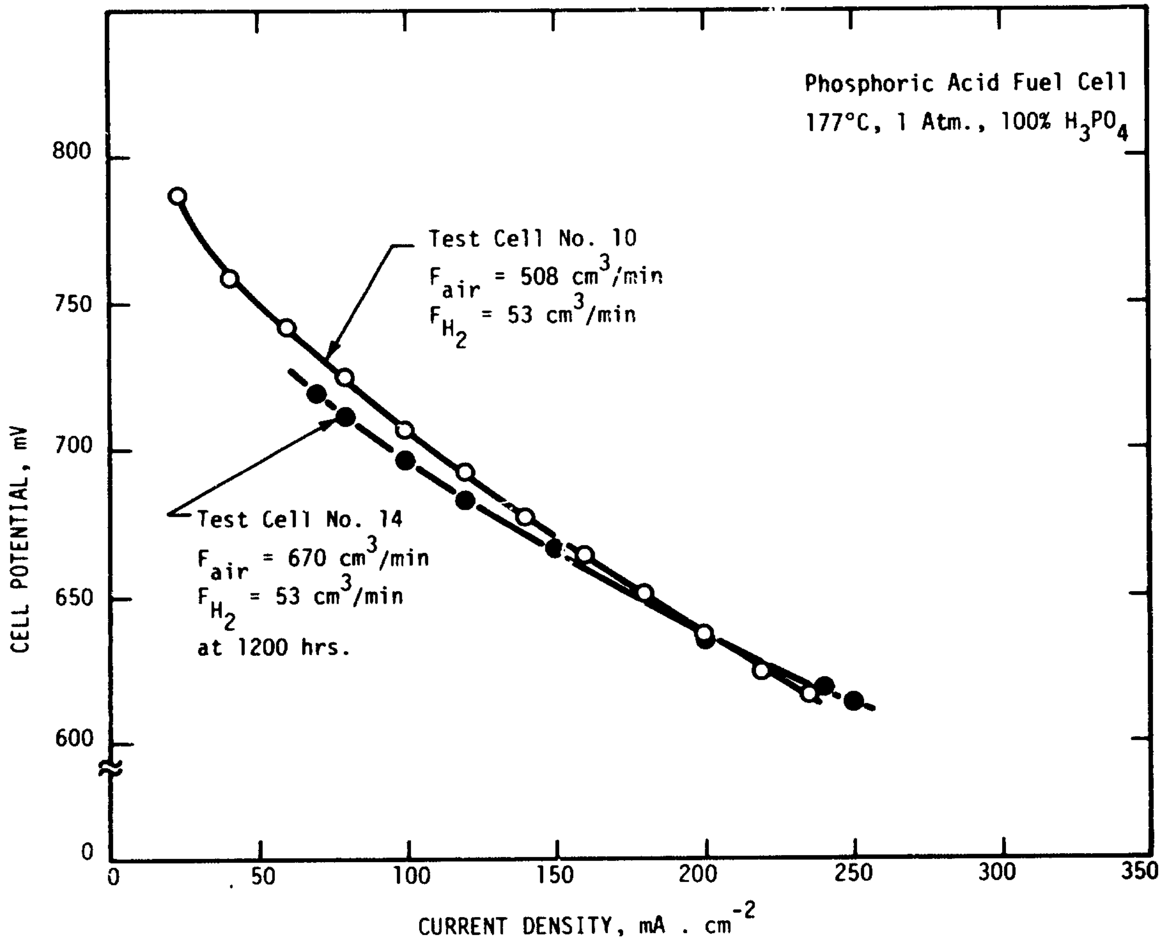

Figure 3.8-2. Performance of Test Cell No's 14 and 10

In accordance with the Contract Modification 7, a Project Control Release (PCR) was issued internally. This PCR defined and authorized the performance of various work elements to develop a PAFC stack design for operation at a higher than atmospheric pressure in compliance with the technical and funding requirements of the contract modification. In addition, responsibilities at the subtask level, lines of internal and external communication, and detail schedular and resource plans were defined.

Technical and programmatic direction for conducting, integrating, controlling and documenting the project was provided. Coordination of efforts among the various cognizant department personnel was continued. Various informal working meetings or sessions and project review meetings were held for purposes of control, review, and progress assessment.

The coordination of this project with ERC programs DEN3-201 and DEN3-205 was continued.

5.2 Documentation and Reporting

The Technical Progress Narrative Reports for July and August, 1981 were prepared and submitted for NASA patent approval. Also, financial management (NASA Form 533M) and Performance Analysis (NASA Form 533P) reports were prepared and submitted for each of the above mentioned periods. The Quarterly Contractor Financial Management (NASA Form 533Q) report for the period beginning October 1, 1981 was prepared and submitted.

A Project Status Review Meeting with the NASA Project manager and other NASA personnel was held at our facilities on September 23, 1981. Copies of all presentation material were provided. Weekly and monthly technical highlights were verbally reported to the NASA project manager.

III. PROBLEMS

There are no technical or schedule problems.

IV. WORK PLANNED

TASK 1: DESIGN OF LARGE CELL STACKS

The 10 kW stack design layout and supporting analysis efforts will be continued, completed, and subjected to a design review early next quarter. Design review

comments will be evaluated and where deemed appropriate incorporated into the layout. Based upon this updated layout drawing, detailed drawings will be completed for all long lead time hardware and released to initiate procurement effort.

The preliminary fuel cell technology constraints report will be updated based upon evaluating ERC and Westinghouse Research and Development Center comments received. The final report will be submitted to NASA in October, 1981.

The power, pressure and temperature levels, and power level control method system trade-off studies will be completed. A report documenting the issued results of this effort will be issued at the end of the next quarter.

Initiate and complete the functional analysis, and document in a report the functional requirements for subsequent translation into requirements for top level plant systems design and hardware specifications. Complete the initial definition of requirements for the fuel cell stack and module developments. Complete a review of industrial fuel processing state-of-the-art technology.

TASK 2: STACK FABRICATION

Complete the procurement of the 23 cell stack (Stack 564 configuration) materials, fabrication of the cell repeatable components, and assembly of the stack. The assembly of this stack will be completed the last month of the next quarter.

Complete the training of manufacturing personnel in the fabrication activities involved with producing the basic fuel cell components, namely the electrodes, matrix, and cooling plates.

Complete and issue previously developed preliminary process and assembly procedures in terms of current manufacturing equipment and established operating practice.

TASK 3: STACK TESTING

Review of the remaining data expected to be received from vendors in response to our inquiries will be completed. This data and that received to date will be utilized to prepare draft procurement specifications for the identified raw materials. These specifications will be submitted to each of the respective vendors for review and comment prior to issuance to NASA.

Raw material characterization effort will be continued next quarter and selected fuel cell component characterizations completed.

Test Cell No. 15 testing will be completed and its performance documented. In addition, all components will be manufactured and assembled and approximately 20 additional subscale tests will be performed and their performance documented. The 25 unit subscale unpressurized test stand facility fabrication and installation activities will be continued. This facility is planned to be completely operational in early November.

TASK 5: MANAGEMENT REPORTING AND DOCUMENTATION

The required technical and programmatic direction for conducting, integrating, coordinating, controlling, and documenting the OS/IES Program will be provided. Bi-monthly status review meetings will continue to be convened to review the schedular status of each subtask.

The Monthly Financial Management Reports (NASA Forms 533M & P) will be prepared and submitted to the NASA LeRC Project Manager. Preparation of the Final Technical Report will be initiated.

A Design Review Meeting of the 10 kW stack being designed for operation at a pressure above one atmosphere is planned for early next quarter. Members of the NASA project team will participate in this review.

A number of technical reports will be submitted next quarter. These reports include: (1) Fuel Cell State-of-the-Art Constraints, (2) System Trade Studies, (3) System/Subsystem Functional Analysis, (4) Cost of Energy Analysis, (5) Development Requirements, (6) Preliminary Cell/Stack Process and/or Assembly Procedures, and (7) Preliminary Cell Raw Materials Requirements. Also, detail design of the 10 kW stack will be completed late next quarter and the drawings submitted.